Tips for Successful Microvascular Abdominal Flap Breast Reconstruction Utilizing the "Total Rib Preservation" Technique for Internal Mammary Vessel Exposure

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Introduction: The internal mammary vessels (IMVs) are increasingly the recipients for free flap breast reconstruction (FFBR). Access traditionally entails removing a segment of the third costal cartilage. Despite excellent exposure, some authors have reported localized tenderness as well as a thoracic contour deformity. We introduced the "total rib preservation" technique for IMV exposure after specific request by a patient, and have used it for all subsequent reconstructions.

Methods: All patients who underwent FFBR with rib preservation by a single surgeon in the year beginning June 2008 were studied prospectively. Intraoperative measurements of the inter-rib space available for microvascular anastomosis were taken. Operative details and flap outcomes were compared with a cohort of earlier patients who underwent rib sacrifice.

Results: Over a 12-month period, 42 FFBRs in 37 patients (36 DIEPs, 5 muscle-sparing TRAMs, and 1 SIEA flap) were performed by a single operator. All flap transfers were successful. In the first 4 patients, the interspace between the third and fourth ribs was used; but for all subsequent patients the second and third rib interspace was used. The average distance between adjacent ribs was 21.3 mm (range, 9–28 mm) and the vessel preparation time decreased from an average of 93 to 49 minutes (first and last 5 cases). There was no significant difference in mean ischemia time between the rib preservation and the rib sacrifice groups (104.4 vs. 103.6 minutes). AQ:2

Conclusions: The total rib preservation method of IMV exposure is a viable, reproducible, and reliable option for microvascular breast reconstruction. It does not increase warm ischemia, which suggests time taken for anastomosis is not affected by rib preservation. There is a learning curve and care has to be taken to avoid possible pitfalls. We recommend the use of a higher rib interspace than originally described because of the greater vessel calibre, superior vessel exposure, and therefore, easier anastomosis.

Key Words: rib-preservation, internal mammary vessels, microvascular breast reconstruction, costal cartilage, recipient site morbidity, prospective assessment

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The internal mammary vessels (IMVs) have increasingly become the first-choice recipients for free flap breast reconstruction (FFBR) world-wide,[1–7] and are used almost exclusively in the senior author's practice. The IMVs have several notable advantages over other recipient sites.[1–3,8–13] These include larger arterial diameter and less demand for a long pedicle compared with the thoracodorsal system, ability of 2 surgeons to sit opposite one another to facilitate microvascular anastomosis (and training), more medial flap placement avoiding lateral fullness and medial emptiness, and avoidance of scarring associated with previous axillary dissection.[12] Additionally, sampling of internal mammary lymph nodes offers an opportunity to accurately stage malignant breast disease and optimize its oncological treatment.[12,14–17] If axillary clearance is not performed by the general surgeons (following negative sentinel-node biopsy),[18] then using the IMV recipient site also avoids interference with the lymphatic drainage of the upper limb. It also spares the thoracodorsal vessels for use in latissimus dorsi flap transfer if the abdominal free flap failed.

Disadvantages of IMV use most commonly relate to fragility of the veins, particularly after radiotherapy, and occasionally anatomic variants, which enforce the use of an alternative recipient site.[13,19–25] Other potential risks of IMV use in FFBR include pneumothorax during blind dissection of the third costal cartilage, intercostal neuralgia, and reduced blood supply to the sternum.[5,7,26–28] A life-threatening case of cardiac tamponade following use of the IMVs has also been reported.[29] Use of the IMVs precludes them from future use in coronary artery bypass surgery.[30]

Access to the IMVs traditionally entails removing a segment of the third costal cartilage to expose the underlying vessels.[1–3,8–12] Despite the excellent ~~(and reliable)~~ exposure, this has been associated with postoperative local pain, long-term tenderness and a contour deformity of the chest wall.[31–33]

In selected cases, it is possible to perform the anastomoses directly to internal mammary perforators, which retains many of the benefits associated with use of the IMVs, and may avoid potential complications.[34–42] Some consider examination of the perforators as the first step in selecting recipient vessels.[43,44]

The contour deformity caused by rib harvest can be~~en~~ reduced by replacing the excised cartilage[33] or filling the defect with muscle.[45] Robot-assisted harvest of the IMVs for breast reconstruction has also been described.[46] In 2008, the technique of dissecting the IMVs in the interspace without rib excision was published—the total rib-preservation technique.[32]

Our use of the total rib-preservation method was prompted by a patient who had read about this on the internet and wished to avoid rib excision. The dramatic subjective reduction in postoperative pain led us to adopt it in all our subsequent reconstructions. This article presents the initial (12-month) experience of a single surgeon (C.M.M.) with the first 42 consecutive microvascular abdominal flap reconstructions (37 patients) using this technique for IMV exposure, and highlights the tips for successful use. Our modifications to the original technique of Parrett et al are also described.

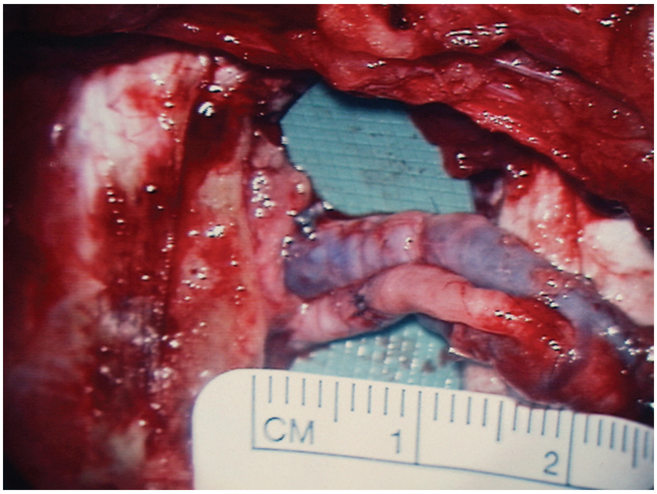

FIGURE 1. Rib interspace measured at the level of the internal mammary artery. Three measurements were taken by the operating surgeons and then an average calculated. This was to eliminate parallax error.

PATIENTS AND METHODS

General

All patients undergoing abdominal FFBR over a 12-month period using the total rib-preservation method of IMV exposure by a single surgeon (C.M.M.) at Addenbrooke's University Hospital (Cambridge) were assessed prospectively. Intraoperatively, 3 measurements of the inter-rib distance were taken to assess the space available for microvascular anastomosis. This was measured at the level of the artery (Fig. 1) as it has a straighter course than the vein and, unlike the vein, is always single (undivided) at this location.[2,3,9,47,48]

Comparison

The indications, operative details, and flap outcomes were compared with FFBRs performed the preceding year (24 patients) by the same operator but using the conventional method of rib sacrifice. The distance between the ribs and the time for vessel dissection were not available for the earlier cohort. A direct comparison was therefore made of the ischemia times (as a measure of difficulty in performing the anastomoses), incidence of re-explorations, and revisions of anastomosis and flap outcomes (loss or necrosis).

Technique

In the first 4 patients, the interspace between the third and fourth ribs was used following the original description by Parrett et al.[32] Subsequently, we used the space between the second and third ribs as this was consistently wider than the third/fourth interspace. This space is identified with reference to the sternal angle of Louis (second rib). The pectoralis major muscle is then split along its fibers between the 2 ribs using monopolar cautery. A self-retaining retractor is inserted to expose the costal cartilages. Sometimes, it is necessary to dissect the mastectomy flap a little beyond the breast boundary to expose the medial end of the second space. The perichondrium on the anterior surface of the second and third costal cartilages is then incised for about 3 cm from the sternal border, and a periosteal elevator is then used to "peel" the perichondrium toward the interspace. With increasing experience, it is not always necessary to resect perichondrium.

Under loupe magnification, resection of the intercostal muscles (with or without perichondrium) is started in the inferolateral corner and advanced medially. The muscle excision to the sternal edge is performed slowly looking for the vessels (identified by perivascular fat) and carefully ligating vessel branches. Using the operating microscope, the internal mammary artery and vein are then separated from the underlying pleura and from each other. Papaverine and warm saline-soaked swabs are then applied to encourage vasodilatation. The artery and the vein are clipped individually and then divided underneath the third rib. Microvascular anastomoses are then performed in the standard fashion.

All the anastomoses were performed end-to-end with 9/0 nylon; continuous for the vein and interrupted for the artery, except for 1 case in which a venous coupler was used. This was on loan, but subsequent funding for this was not approved at our institution.

Statistical Analysis

Significance was determined using the following statistical tests: χ^2 test, 2-tailed unpaired *t* test, Mann-Whitney *U* test, Pearson correlation (Microsoft Excel and Interactive Statistical Calculation Pages (available at: http://statpages.org/), $P < 0.05$.

RESULTS

Over the 12-month period (June 2008–June 2009), 37 patients underwent 42 abdominal FFBRs by the senior author (C.M.M.), using the total rib-preservation technique to access the IMVs. Their mean age was 5[illegible]rs (range, 34–64). The first 4 patients had perichondriectomy of the third and fourth ribs and the next 33 patients (38 reconstructions) underwent IMV exposure via the second and third rib interspace because of better access. Five bilateral reconstructions each had bilateral rib preservation. The timing of the reconstructions was immediate in 24 patients (29 flaps) and delayed in 13 patients (13 flaps). The flaps used were 36 ~~DIEPs, 5 muscle-sparing II TRAMs, and 1 SIEA flap~~.

The time taken for vessel dissection was 63 ± 23 minutes (mean ± standard deviation) (Table 1). For the sake of consis-

TABLE 1. Comparison of Operative Details and Outcomes in Patients Undergoing Abdominal Free Flap Breast Reconstruction With and Without Rib Preservation

	Rib Preservation June 2008–2009	Standard Exposure June 2007–2008
No. patients (flaps)	37 (42)	24 (30)
Mean age (range)	51 (29–64)	46 (21–62)
Mean BMI (mean ± SD)	29.3 ± 6.7	28.3 ± 5.4
Immediate:delayed	29:13	25:5
IMV Dissection time (mean, range)	63 (25–106)	Not recorded
Warm ischaemia time (mean ± SD)	104.4 ± 13.9	103.6 ± 33.2
Flap success rate	100%	100%
Flap partial necrosis	0	0
Recipient site morbidity		
Localised tenderness/pain	0	2
Contour deformity	0	1
Pneumothorax	0	1
Expanding haematoma*	1	0

*An expanding haematoma on day 5 postoperatively following therapeutic heparinisation for a suspected stroke. This was the only re-exploration in the 2 year period.

BMI indicates body mass index; SD, standard deviation; IMV, internal mammary vessels.

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tency, we started timing when the plastic surgeon began to operate on the patient's chest. This included time taken to excise the mastectomy scar and raise the skin flaps in delayed reconstructions, and also bringing in/setting up the microscope for final preparation of the vessels.

The mean time for the first 5 cases was 93 ± 19 minutes compared with 49 ± 12 minutes for the most recent 5 cases (*t* test, $P = 0.004$). The mean distance between the 2 adjacent ribs was 21.6 mm (range, 9–28 mm). The second patient in the series had a very narrow interspace that was too tight for microvascular anastomoses so a small amount of cartilage was excised from the third rib to optimize access. This was not required in any of the subsequent cases.

The mean ischemia time was 104.4 ± 13.9 minutes (mean ± standard deviation) (range, 76–141 minutes) compared with 103.6 ± 33.2 minutes (range, 55–228 minutes) in the rib sacrifice group. This difference was not significant (Mann-Whitney *U* test, $P = 0.69$).

It was significantly more common to use 1 vein in the
F2 rib-sparing patients compared with previously (Fig. 2). There was no statistical correlation between inter-rib distance and time taken for
F3-4 the vessel dissection or the warm ischemia time (Figs. 3, 4).

All flaps were successful, and there were no partial flap failures or fat necrosis (Table 1). There was 1 re-exploration for hematoma while 3 arterial anastomoses were revised on-table for occlusion or excessive leakage. All 3 revisions were easily accomplished without resorting to removal of the second rib. Additionally, a vein graft was employed (from the SIEV) in a patient in whom we felt the DIEP flap had borderline venous adequacy at the end of
AQ:3 gery.

None of the patients in the rib-preservation group have so far (maximum follow-up = 18 months) complained of pain at this site or noticed a contour deformity. No chest wall deformity has been obvious on examination or on postoperative photographs
F5-6, AQ:9 (Figs. 5, 6).

DISCUSSION

Why Rib Preservation?

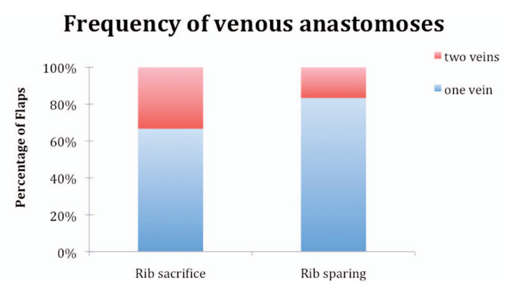
We began using the rib-preserving technique to access the IMVs after a specific request by a patient, who was fearful of the prospect of losing part of a rib. Other authors have described complications of rib resection such as a chest wall contour deformity or increased postoperative pain as motivation for developing rib-sparing techniques.[37,31,32,45] However, in our clinical experience, these problems were not previously perceived to be major issues.

This technique may be safer than harvesting a rib because the vessels may adhere to the back of the rib and be damaged when the costal cartilage is dissected free from the perichondrium. It is easy to teach because no specialized instruments are required (such as pig-tail rib dissectors).

Technical Tips

Use the Second Intercostal Space

After the first 4 cases, we switched to the space cranial to the third rib principally because the third to fourth interspace provided less access for anastomoses. In the second–third interspace, we found the diameter of both vessels to be larger and the veins usually united.[2,3,47] Caudal to the third rib there were usually 2 small veins prior to their confluence (though some may prefer this to allow 2 venous anastomoses). These findings have also been independently



	Rib Sacrifice	Rib sparing
TwoVeins	10	7
One Vein	20	35

* $\chi^2 = 0.001$

FIGURE 2. Frequency of double vein anastomoses decreased with rib-sparing approach to IMVs.

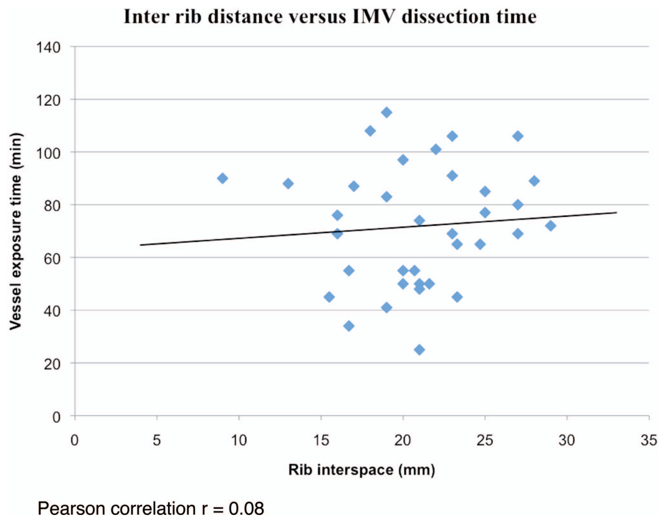


FIGURE 3. Relationship between rib interspace and vessel exposure time.

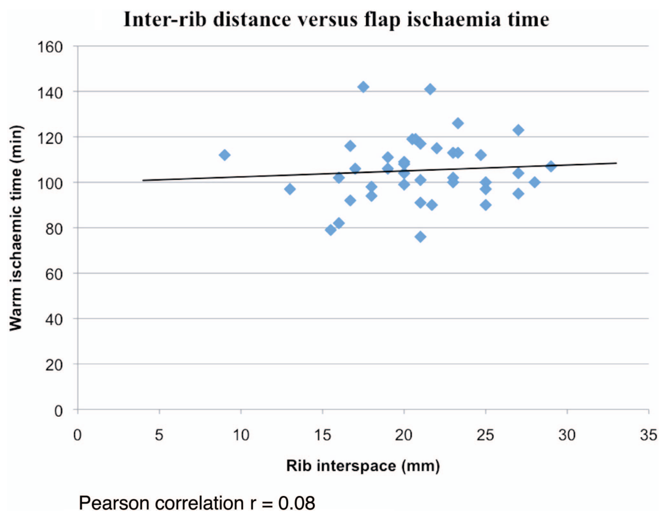


FIGURE 4. Relationship between rib interspace and warm ischemic time.

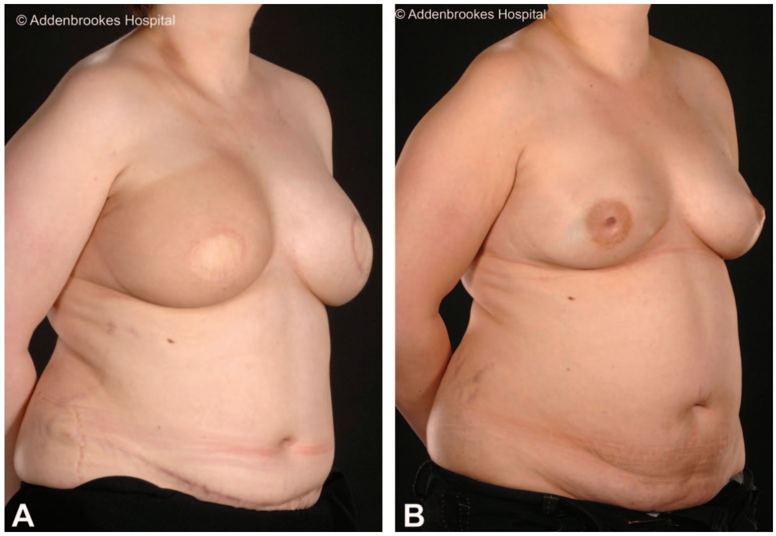


FIGURE 5. Pre-, and postoperative photographs of a 39-year-old patient who underwent bilateral immediate DIEP flap breast reconstruction using the rib-sparing technique. She has had postoperative radiotherapy to the right breast and is currently awaiting nipple reconstruction. Please note the fullness of the superior poles;

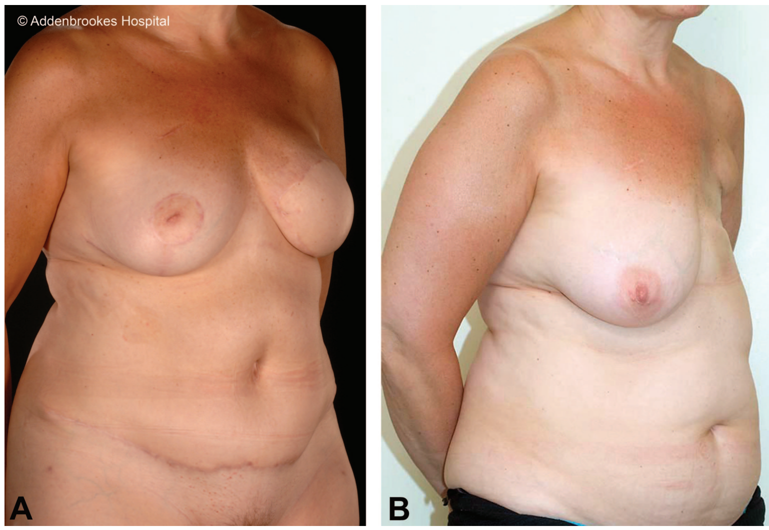


FIGURE 6. A 45-year-old patient who underwent delayed left breast reconstruction, with a DIEP flap and simultaneous contralateral balancing breast reduction. She is especially pleased with the cleavage and superior fullness attained;

reported by Chang's group.[49] We therefore now use this space preferentially.

Keep the, Muscle (±Perichondrial) Excision to Medial 2 to 3 cm

The extensive dissection originally described[32] is unnecessary because the vessels are located within 3 cm of the sternum; the lateral vein lies within 24 mm of the lateral border of the sternum.[3] Because there is no perivascular fat, lateral dissection endangers the pleura unnecessarily.

Transfix the Vein Caudally (if Possible)

Because the vein confluence may be under the third rib[3,47,50] injudicious clip application may lead to bleeding in an inaccessible location. We therefore preferred to transfix the IM vein at the caudal end (ie, just underneath the third rib); AQ:4

Judicious Resection of the Costal Cartilage to Optimize Exposure and Facilitate Anastomosis

If access is difficult the available space can be increased by resection of up to 1/2 of the circumference of the third costal cartilage using a bone rongeur.[32,49] This still preserves the integrity of the rib and its contour. Although Sacks and Chang have reported using this in up to a third of their cases,[49] we have never had to do this when using the second ICS. It may be helpful when, adopting this technique and is made easier by performing a partial perichondriectomy when excising the intercostal muscles. AQ:5

Conversion to Rib Sacrifice

Although this has been suggested for postradiation cases or in cases of suboptimal access, we have not found this necessary.[32] It is thought that the vessels underneath the ribs are somewhat "protected" from radiotherapy and therefore less friable. All our delayed reconstructions were postradiation; subjectively, we found no difference in terms of the quality of the vessels. This may be related to the different radiotherapy regimens in the United Kingdom and the United States.[51]

Keep the Intercostal Nerve Above the Vessels

Resist the temptation to transpose the vessels above the nerve as the vein may become kinked over the nerve. Preserve the nerve if possible (rather than dividing it) to retain some medial native breast skin sensation. Additionally, preservation of the intercostal nerve may prevent some of the chest wall discomfort described by some patients postoperatively.

Loose Approximation of Pectoralis Muscle Split

After successful anastomosis, loosely approximate the split pectoralis muscle. We have not found this to constrict our vascular pedicle. This maneuver may in fact give the vessels some support and prevent kinking in a similar manner to the use of autologous fat grafts recently described by Bar Meir et al.[52]

Standard Anastomotic Suture Technique

We have found that a double Acland clamp can be easily rotated in the space (during anastomosis of the front and back walls of the vessels) without undue tension, twisting, or damage of the vessels. We would encourage surgeons to use whatever suture method they feel most comfortable with. We successfully used a vein coupler in 1 case.[39]

Use Long-Handled Microvascular Instruments

A total of 210 mm length instruments (S&T, Neuhausen, Switzerland) facilitated the IMV dissection and anastomosis. Use of
F7 visibility background material (Fig. 7) not only provided contrast but also helped to elevate the vessels so that the anastomoses can be done more superficially. This elevation is more important in patients with thick ribs in whom the vessels lie in a "deep" hole.

Disadvantages of Total Rib Preservation for IMV Access

1. It is undeniable that the space available with rib sparing access is less than if costal cartilage has been resected. The relatively tight space for microvascular anastomosis: is not insurmountable by experienced microvascular surgeons. As mentioned earlier, we found the use of long-handled microsurgical instruments and a visibility background helped mitigate against this.
2. There is a learning curve before becoming comfortable with this approach as illustrated by the decreasing dissection time with increased experience. This is however short; probably just a few cases for surgeons used to routinely performing anastomosis to the IMVs.

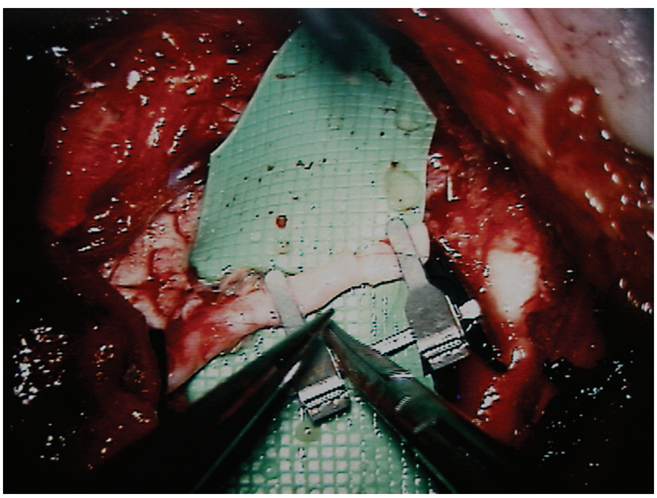


FIGURE 7. Use of long-handled microvascular instruments and visibility background to facilitate easier anastomoses.

3. In the eventuality of a flap failure, it might be difficult to expose the IMVs any higher in the chest to anastomose another free flap. In that case, we would probably use the thoracodorsal vessels. However, in our unit's experience, no patient with a flap failure has opted for a second reconstruction with a free flap; all have had pedicled latissimus dorsi flap reconstructions.

Reducing Morbidity in FFBR

Since breast reconstruction with TRAM flaps was described by Hartrampfin 1982,[53] there has been a stepwise reduction in donor site morbidity. This has been achieved by progression from pedicled to free flaps, then to muscle-sparing and lastly perforator-based flaps.[8,54,55] Similarly, progression from rib-resection to rib-sparing techniques represents the next step in reduction of free flap morbidity, this time at the recipient site, whether achieved in the manner we describe, with endoscopic/robotic techniques[46] or by anastomosis to a perforator.[34–37,39,43,44]

We believe that anastomosis to the IMVs with total rib-preservation is more reliable than anastomosis to a perforator because the vessels are larger, have increased flow and are consistently present; whereas the internal mammary perforators are not always present, may be small or may have been damaged by diathermy. In our experience, the perforators go into spasm more often and the vein is more prone to clotting. Rib preservation in our hands was as reliable as but requires less invasive surgical dissection than rib sacrifice.

Additionally, subjectively, there seems to be a reduction in the pain reported by the patients.[57] This is not surprising because the pain experienced postoperatively is thought to be related to rib resection[58] or to damage to the intercostal nerves at the time of vessel harvest.[27,59,60] We are currently evaluating the analgesia requirements in patients with rib-sacrifice versus those with rib-preservation breast reconstructions in an attempt to quantify any difference in postoperative pain.

It is difficult to evaluate the effect on the chest wall contour—which is related to many other factors such as how the flap inset is performed, whether the patient has had any postoperative radiotherapy, whether there is any fat necrosis and whether or not the reconstruction is immediate.

Although this is not a novel technique having been described by Parrett et al in March 2008 our successful adoption 2 months later shows that this technique can be successfully reproduced by independent surgeons and confirms that it is reliable and safe. Although we started using the technique after a rather unusual patient request, we have developed the technique further. We are able to highlight particular technical points to make the process easier for other microvascular surgeons interested in switching to rib-preservation. In particular, we present an important modification of the original technique, ie, the exclusive use of the second intercostal space (between the second and third costal cartilages) rather than the third interspace as originally described.

CONCLUSION

In this single-operator series, it has been confirmed that total rib-preservation is a safe alternative to rib-resection for IMV exposure. It is reliable and reproducible and led to successful FFBR without increasing ischemic time or complications (when compared with rib sacrifice). It subjectively minimized local recipient site pain. We recommend the use of this technique of rib-preservation to access the IMVs in the second ICS for FFBR.

REFERENCES

1. Nejedlý A, Tvrdek M, Kletenský J, et al. Internal mammary vessels as recipient vessels to the free TRAM flap. *Acta Chir Plast*. 1995;37:17–19.

2. Hefel L, Schwabegger A, Ninković M, et al. Internal mammary vessels: anatomical and clinical considerations. *Br J Plast Surg*. 1995;48:527–532.
3. Arnez ZM, Valdatta L, Tyler MP, et al. Anatomy of the internal mammary veins and their use in free TRAM flap breast reconstruction. *Br J Plast Surg*. 1995;48:540–545.
4. Dupin CL, Allen RJ, Glass CA, et al. The internal mammary artery and vein as a recipient site for free-flap breast reconstruction: a report of 110 consecutive cases. *Plast Reconstr Surg*. 1996;98:685–689; discussion 690–692.
5. Majumder S, Batchelor AG. Internal mammary vessels as recipients for free TRAM breast reconstruction: aesthetic and functional considerations. *Br J Plast Surg*. 1999;52:286–289.
6. Quaba O, Brown A, Stevenson H. Internal mammary vessels, recipient vessels of choice for free tissue breast reconstruction? *Br J Plast Surg*. 2005;58:881–882.
7. Saint-Cyr M, Youssef A, Bae HW, et al. Changing trends in recipient vessel selection for microvascular autologous breast reconstruction: an analysis of 1483 consecutive cases. *Plast Reconstr Surg*. 2007;119:1993–2000.
8. Blondeel PN, Boeckx WD. Refinements in free flap breast reconstruction: the free bilateral deep inferior epigastric perforator flap anastomosed to the internal mammary artery. *Br J Plast Surg*. 1994;47:495–501.
9. Ninković M, Anderl H, Hefel L, et al. Internal mammary vessels: a reliable recipient system for free flaps in breast reconstruction. *Br J Plast Surg*. 1995;48:533–539.
10. Arnez ZM, Khan U. The internal mammary artery and vein as a recipient site for free-flap breast reconstruction. *Plast Reconstr Surg*. 1997;100:1359–1360.
11. Ninković MM, Schwabegger AH, Anderl H. Internal mammary vessels as a recipient site. *Clin Plast Surg*. 1998;25:213–221.
12. Moran SL, Nava G, Behnam AB, et al. An outcome analysis comparing the thoracodorsal and internal mammary vessels as recipient sites for microvascular breast reconstruction: a prospective study of 100 patients. *Plast Reconstr Surg*. 2003;111:1876–1882.
13. Temple CL, Strom EA, Youssef A, et al. Choice of recipient vessels in delayed TRAM flap breast reconstruction after radiotherapy. *Plast Reconstr Surg*. 2005;115:105–113.
14. Hofer SO, Rakhorst HA, Mureau MA, et al. Pathological internal mammary lymph nodes in secondary and tertiary deep inferior epigastric perforator flap breast reconstructions. *Ann Plast Surg*. 2005;55:583–586.
15. Arnez ZM, Snoj M. Sampling of internal mammary chain lymph nodes during breast reconstruction by free flaps from the abdomen. *Tumori*. 2005;91:415–417.
16. Salim F, Mehrara B, Mosahebi A. The routine sampling of internal mammary nodes as part of breast reconstruction. *J Plast Reconstr Aesthet Surg*. 2008;61:1419.
17. Knight MA, Nguyen DT, Kobayashi MR, et al. Incidental positive internal mammary lymph nodes: a multiple international institutional investigation. *J Reconstr Microsurg*. 2008;24:197–202.
18. Kronowitz SJ, Kuerer HM, Hunt KK, et al. Impact of sentinel lymph node biopsy on the evolution of breast reconstruction. *Plast Reconstr Surg*. 2006;118:1089–1099.
19. Kavouni A, Shibu M. Problems associated with the use of internal mammary vessels as recipients for free flap breast reconstruction. *Br J Plast Surg*. 1999;52:597.
20. Serletti JM, Moran SL, Orlando GS, et al. Thoracodorsal vessels as recipient vessels for the free TRAM flap in delayed breast reconstruction. *Plast Reconstr Surg*. 1999;104:1649–1655.
21. Lorenzetti F, Kuokkanen H, von Smitten K, et al. Intraoperative evaluation of blood flow in the internal mammary or thoracodorsal artery as a recipient vessel for a free TRAM flap. *Ann Plast Surg*. 2001;46:590–593.
22. Al-Benna S, Grob M, Mosahebi A, et al. Caution note on the use of the internal mammary artery in breast reconstruction. *Plast Reconstr Surg*. 2006;117:1653–1654.
23. Nahabedian MY. Cautionary note on the use of the internal mammary artery in breast reconstruction. *Plast Reconstr Surg*. 2007;119:425–426.
24. Snelling AP, Mosahebi A, Pereira J, et al. Use of the internal mammary vessels in breast reconstruction: a cautionary note. *Plast Reconstr Surg*. 2007;119:1626–1627.
25. Al-Benna S. Caution in the use of the internal mammary artery in breast reconstruction. *Plast Reconstr Surg*. 2007;120:348.
26. Carrier M, Gregoire J, Tronc F, et al. Effect of internal mammary artery dissection on sternal vascularization. *Ann Thorac Surg*. 1992;53:115–119.
27. Conacher ID, Doig JC, Rivas L, et al. Intercostal neuralgia associated with internal mammary artery grafting. *Anaesthesia*. 1993;48:1070–1071.
28. Knudsen FW, Andersen M, Niebuhr U, et al. The role of the internal thoracic artery in the sternal blood supply. *Scand J Thorac Cardiovasc Surg*. 1993;27:3–8.
29. Pratt GF, Faris JG, Lethbridge M, et al. Breast reconstruction with a free DIEP (TRAM) flap complicated by cardiac tamponade and arrest: a case report. *J Plast Reconstr Aesthet Surg*. 2009;62:e73–e75.
30. Nahabedian MY. The internal mammary artery and vein as recipient vessels for microvascular breast reconstruction: are we burning a future bridge? *Ann Plast Surg*. 2004;53:311–316.
31. Levine JL, Allen RJ, Khoobehi K. Opened book technique for accessing the internal mammary vessels for microanastomosis. *J Reconstr Microsurg*. 2006;22. AQ:6
32. Parrett BM, Caterson SA, Tobias AM, et al. The rib-sparing technique for internal mammary vessel exposure in microsurgical breast reconstruction. *Ann Plast Surg*. 2008;60:241–243.
33. Schoeller T, Schubert HM, Wechselberger G. Rib cartilage replacement to prevent contour deformity after internal mammary vessel access. *J Plast Reconstr Aesthet Surg*. 2008;61:464–466.
34. Guzzetti T, Thione A. Successful breast reconstruction with a perforator to deep inferior epigastric perforator flap. *Ann Plast Surg*. 2001;46:641–643.
35. Park MC, Lee JH, Chung J, et al. Use of internal mammary vessel perforator as a recipient vessel for free TRAM breast reconstruction. *Ann Plast Surg*. 2003;50:132–137.
36. Haywood RM, Raurell A, Perks AG, et al. Autologous free tissue breast reconstruction using the internal mammary perforators as recipient vessels. *Br J Plast Surg*. 2003;56:689–691.
37. Munhoz AM, Ishida LH, Montag E, et al. Perforator flap breast reconstruction using internal mammary perforator branches as a recipient site: an anatomical and clinical analysis. *Plast Reconstr Surg*. 2004;114:62–68.
38. Rosson GD, Holton LH, Silverman RP, et al. Internal mammary perforators: a cadaver study. *J Reconstr Microsurg*. 2005;21:239–242.
39. Rad AN, Flores JI, Rosson GD. Free DIEP and SIEA breast reconstruction to internal mammary intercostal perforating vessels with arterial microanastomosis using a mechanical coupling device. *Microsurgery*. 2008;28:407–411.
40. Nakatani K, Maeda H, Tanaka Y, et al. Perforating branches of the internal thoracic artery in women with breast cancer: an anatomical study for breast-conservation surgery. *Oncol Rep*. 2008;19:1299–1303.
41. Munhoz AM. Internal mammary perforator recipient vessels for breast reconstruction using free TRAM, DIEP, and SIEA flaps. *Plast Reconstr Surg*. 2008;122:315–316.
42. Schmidt M, Aszmann OC, Beck H, et al. The anatomic basis of the internal mammary artery perforator flap: a cadaver study. *J Plast Reconstr Aesthet Surg*. 2010;63:191–196.
43. Hamdi M, Blondeel P, Van Landuyt K, et al. Algorithm in choosing recipient vessels for perforator free flap in breast reconstruction: the role of the internal mammary perforators. *Br J Plast Surg*. 2004;57:258–265.
44. Saint-Cyr M, Chang DW, Robb GL, et al. Internal mammary perforator recipient vessels for breast reconstruction using free TRAM, DIEP, and SIEA flaps. *Plast Reconstr Surg*. 2007;120:1769–1773.
45. Mosahebi A, Da Lio A, Mehrara BJ. The use of a pectoralis major flap to improve internal mammary vessels exposure and reduce contour deformity in microvascular free flap breast reconstruction. *Ann Plast Surg*. 2008;61:30–34.
46. Boyd B, Umansky J, Samson M, et al. Robotic harvest of internal mammary vessels in breast reconstruction. *J Reconstr Microsurg*. 2006;22:261–266.
47. Clark CP, Rohrich RJ, Copit S, et al. An anatomic study of the internal mammary veins: clinical implications for free-tissue-transfer breast reconstruction. *Plast Reconstr Surg*. 1997;99:400–404.
48. Schwabegger AH, Milomir N. Internal mammary artery and vein. *Plast Reconstr Surg*. 1997;100:1360–1361.
49. Sacks JM, Chang DW. Rib-sparing internal mammary vessel harvest for microvascular breast reconstruction in 100 consecutive cases. *Plast Reconstr Surg*. 2009;123:1403–1407.
50. Schwabegger AH, Ninković MM, Moriggl B, et al. Internal mammary veins: classification and surgical use in free-tissue transfer. *J Reconstr Microsurg*. 1997;13:17–23.
51. Whitfield GA, Horan G, Irwin MS, et al. Incidence of severe capsular contracture following implant-based immediate breast reconstruction with or without postoperative chest wall radiotherapy using 40 Gray in 15 fractions. *Radiother Oncol*. 2009;90:141–147.
52. Bar-Meir ED, Yueh JH, Tobias AM, et al. Autologous fat grafting: a technique for stabilization of the microvascular pedicle in DIEP flap reconstruction. *Microsurgery*. 2008;28:495–498.

53. Hartrampf CR, Scheflan M, Black PW. Breast reconstruction with a transverse abdominal island flap. *Plast Reconstr Surg*. 1982;69:216–225.
54. Allen RJ, Treece P. Deep inferior epigastric perforator flap for breast reconstruction. *Ann Plast Surg*. 1994;32:32–38.
55. Weiler-Mithoff E, Hodgson EL, Malata CM. Perforator flap breast reconstruction. *Breast Dis*. 2002;16:93–106.
56. Malata CM, McIntosh SA, Purushotham AD. Immediate breast reconstruction after mastectomy for cancer. *Br J Surg*. 2000;87:1455–1472.
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57. Mickute Z, DiCandia M, Moses MA, et al. A retrospective comparison of analgesia requirements in patients undergoing free flap breast reconstruction with and without total rib preservation. *Br J Surg*. 2009;96:24.
58. Srivastava A, Tripathi DM, Zaman W, et al. Subcostal versus transcostal mini donor nephrectomy: is rib resection responsible for pain related donor morbidity. *J Urol*. 2003;170:738–740.
59. Mailis A, Umana M, Feindel CM. Anterior intercostal nerve damage after coronary artery bypass graft surgery with use of internal thoracic artery graft. *Ann Thorac Surg*. 2000;69:1455–1458.
60. Eisenberg E, Pultorak Y, Pud D, et al. Prevalence and characteristics of post coronary artery bypass graft surgery pain (PCP). *Pain*. 2001;92:11–17.

AUTHOR QUERIES

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AQ1—Please check whether the author name "Michele Di Candia" is appropriate as typeset.

AQ2—Please expand DIEP, TRAM, and SIEA at their first occurrences in the abstract as well as in text.

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